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*PHOTOGRAPHIC OBSERVATIONS OF THE  
TRANSIT OF VENUS.*

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BY PROF. ASAPH HALL, NAVAL OBSERVATORY, WASHINGTON, D. C.

EDITOR ANALYST:

I was so busy during my absence, besides being cut off from the mail, that I failed to keep my promise to write you. Let me try to make amends now by giving you a short account of the photographic operations.

The plan adopted by the American Commission for making photographs of the Transit of Venus is now pretty well understood. It consists simply of a lens of 38 to 40 feet focal length, so placed that its axis lies in the meridian, and is made horizontal by means of a spirit level. This lens is mounted on an iron pier firmly set in the ground, and south of this lens, at its focus, is fixed the plate holder, also mounted on an iron pier. The plate holder carries the sensitive plate, and directly in front of this plate a plumb line of fine silver wire. In front of the plumb line is firmly fixed to the plate holder a well made plate of clear glass, on which are finely etched two sets of straight lines, the lines being half an inch apart and the sets at right angles to each other. The distance from the north surface of the ruled glass plate to the surface of the sensitive plate is half an inch. On every photograph we have therefore traces of the ruled or etched lines and of the plumb line. North of the lens is placed a heliostat which moves a plane glass mirror so that the sun's rays are reflected through the lens to the sensitive plate. The whole apparatus is simple, it is firmly mounted, and it gives the means of determining accurately the polar coordinates of a point on the photograph with respect to an assumed point.

First we have a photograph of the sun, very nearly a circle four inches in diameter, and we note and record the instant of local time when the slide passes and admits the sun's rays and this photograph is made. For this instant we can compute for the known latitude of the station the position of the sun in the heavens, and hence the angular distance from the bottom or top of the photograph to the north point of the sun's image. The trace of the plumb line furnishes a known direction to which the measurement of the angles may be referred. If therefore we assume a point as the sun's center we can determine by measuring the photograph with a position micrometer the position angle of any other point, as the center of venus, with respect to the plumb line, or to a declination circle passing from the pole of the heavens through the center of the sun. This position angle can be found, I think, with much greater accuracy than it can be with an equatorial telescope, and here is one advantage of the American method. Secondly we must have

the means of converting any distance, say an inch, on the photograph very exactly into are; so that if we measure the distance between the two points and convert it in to are we have the second polar coordinate. This conversion can be made if we know the distance from the surface of the lens to the surface of the sensitive plate, just as we find the angular value of a micrometer screw by measuring the focal distance of the objective and counting the number of threads of the screw to an inch. The distance between the surfaces has been measured with an accuracy that seems much within the limits required. We have therefore the second polar coordinate and the solution is theoretically complete.

But in order to establish the usefulness of the photographic method it remains to be shown that the photographs can be made in distant places transported thousands of miles through great change of temperature, that the collodion film is subject to no contraction or change except such as can be fully accounted for in the measurement and calculation, and finally that their linear measurement can be made with the required accuracy. We may easily get some idea of the accuracy required in the measurements of the photographs. The sun's diameter is about 32 minutes of arc, and the photographs being 4 inches in diameter we shall have  $\frac{1}{1000}$  of an inch equal to  $0''.48$ , and  $\frac{1}{10000}$  of an inch equal to  $0''.05$ . The photographs to be measured are the negatives on the glass plates, and on these Venus appears as a round vacant spot  $\frac{1}{8}$  of an inch in diameter. As this spot is a symmetrical one, and generally well defined it is probable that the pointings on this spot can be made with sufficient accuracy. The difficulty will be in fixing the position of the sun's center. This can be done only by proceeding from the edge of the photograph, and the edge, or limb, of the sun is a very difficult thing to deal with, on account of its inequalities. Here perhaps some assistance may be derived from the systems of ruled lines, which are designed to control any contraction of the collodion film, and which may be used as a system of rectangular coordinates to which the centers of the sun and Venus may be referred.

We have now at the Naval Observatory a number of photographs from different stations, and shall probably soon know with what accuracy they can be measured.

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### *SOLUTIONS OF PROBLEMS.*

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Solutions of problems in No. 2 have been received as follows:

From J. M. Arnold, 63; A. L. Baker, 61 & 65; W. W. Beman, 59, 60,